EQUIPMENT SUITABILITY GROUP

Test Report

on the

Piezo Ceramic Shear Tube Contact Transducer (Prototype SWM-25) ESG Project 69-156

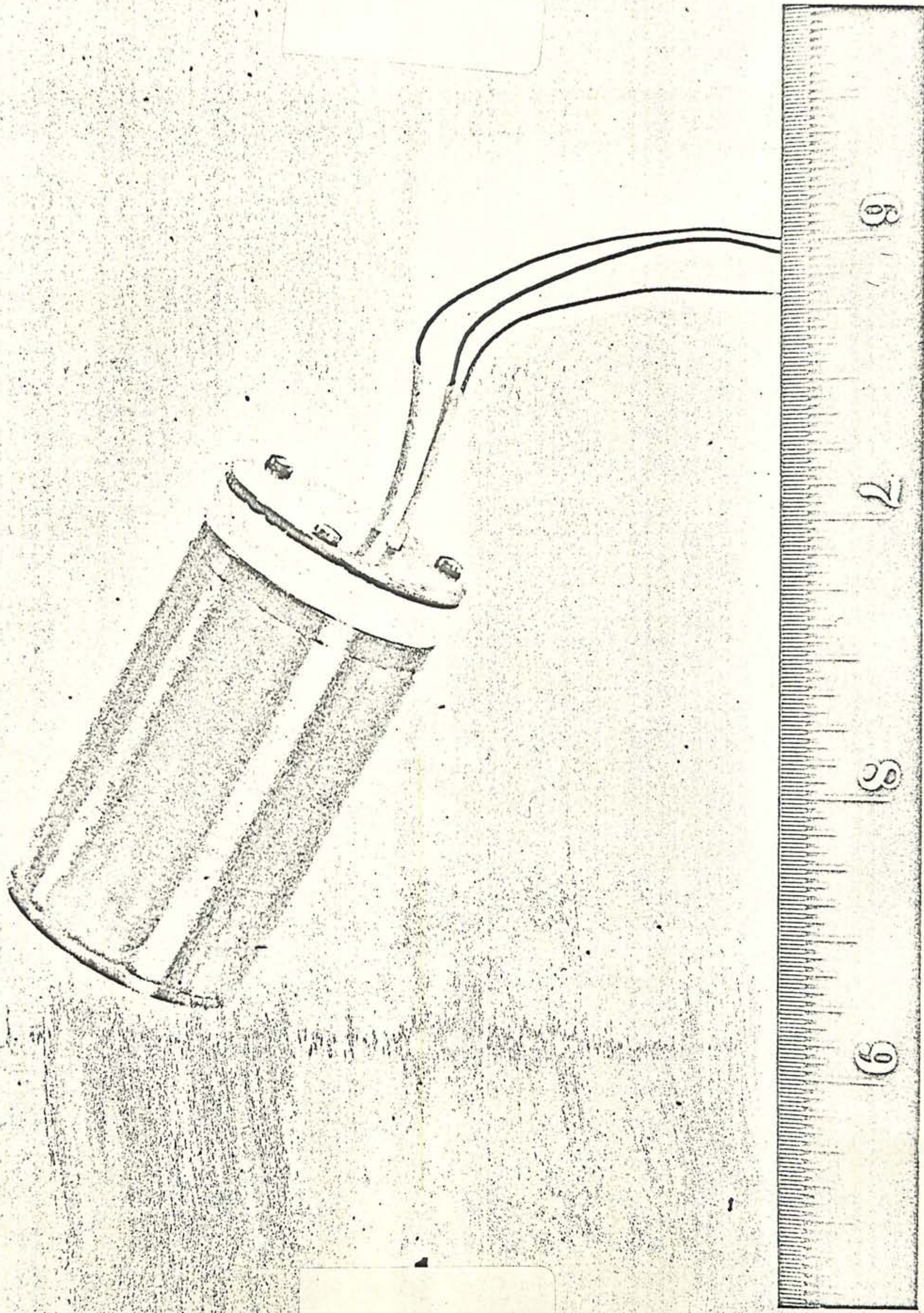
I. INTRODUCTION

A. Three Prototype Piezo Ceramic Shear Tube Contact Transducers were submitted to ESG for electrical and environmental testing. Three units of the engineering model were previously submitted to ESG for testing, however, all three transducers were withdrawn for operational use in the field after relative sensitivity was determined but before any ESG testing could be conducted (relative sensitivity measurements were determined with the units mounted on a 4' x 4' x 3/4" plywood panel).

B. The basic difference between the engineering model (called the pinholeless microphone) and the prototype version is that the internal FET amplifier has been replaced, in the prototype version, with a two-stage bipolar transistor amplifier designed to operate on one mercury cell. The nominal supply voltage is 1.2 to 1.5 volts and the amplifier draws approximately 34 μ amps. The nominal gain of the internal amplifier is the same as the original FET amplifier, but the frequency response has been modified to obtain some high frequency pre-emphasis. The output impedance of the amplifier is about 3500 Ω to allow the transducer to be used with equipment designed for inputs from miniature magnetic microphones with impedances of 2000 to 4000 Ω.

Group I
Excluded from Automatic
Downgrading and Declassification

C. In external appearance the transducer is a brass cylinder one inch in diameter and 1 25/32" long. A white silastic spacer, 5/32" thick, is sandwiched between the transducer and a circular back plate (see Figure 1). Grease sealant has been used to fill the voids around the leads.



II. CONCLUSIONS

A. The physical size of the transducer makes it suitable for operational use.

B. The unit is approximately 20 dB more sensitive to vibration signals on-axis than it is to signals 90° off axis.

C. Two different sources of noise will be present in the operational application of the devices, low frequency noise from the wall environment and higher frequency amplifier noise. Changes of 6 dB in the amplifier noise were observed in unit #2 during electrical testing. The low frequency sensitivity is less than that of the engineering model when mounted on a 4' x 4' x 3/4" plywood panel.

D. The response at frequencies below 500 Hz, although not excessive, is still significantly higher than would be desirable. Most wall environments will probably be sources of high energy low frequency noise. The bottom curve of Figure 2 illustrates a more desirable low frequency characteristic.

E. During the high temperature storage test oil leaked out of the transducer. The grease sealant and silastic washer were apparently not sufficient to prevent leakage when heat caused some expansion to occur.

F. In two out of the three operational tests run, the audio was considered comparable with that obtainable from a microphone/pinhole combination. Additional installations in urban areas in multi-story buildings where wall noise is generally a problem will be used for further operational tests when facilities are available.

G. Although fairly rugged, the small thin wires were difficult to work with.

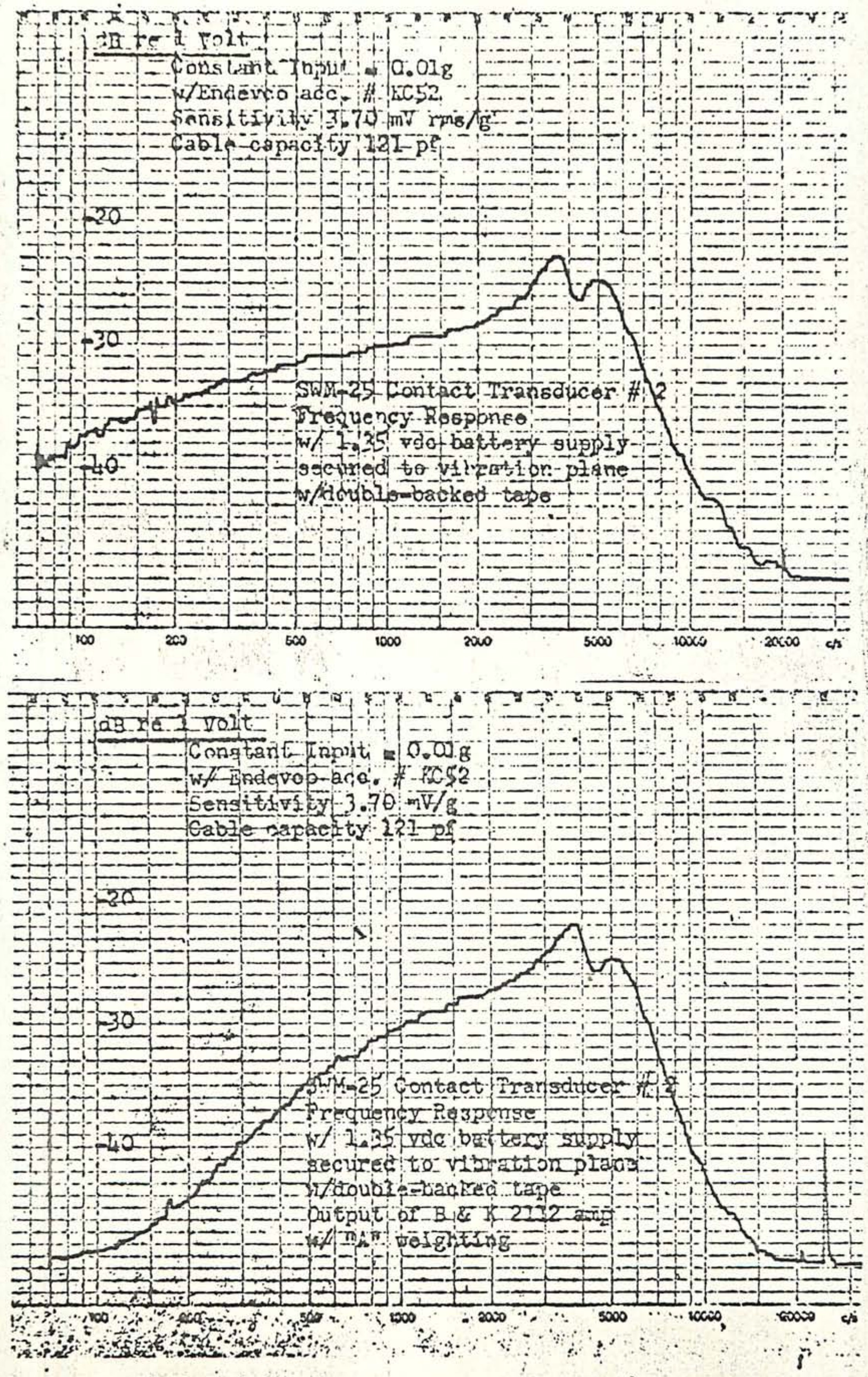

dB re 1 Volt
Constant Input = 0.01g
w/Endevco acc. # KC52
Sensitivity 3.70 mV rms/g
Cable capacity 121 pf
-20
-30
-40
SWM-25 Contact Transducer # 2
Frequency Response
w/ 1.35 vdc battery supply
secured to vibration plane
w/double-backed tape
100
200
500
1000
2000
5000
10000
20000
c/s
dB re 1 Volt
Constant Input = 0.01g
w/ Endevco acc. # KC52
Sensitivity 3.70 mV/g
Cable capacity 121 pf
-20
-30
-40
SWM-25 Contact Transducer # 2
Frequency Response
w/ 1.35 vdc battery supply
secured to vibration plane
w/double-backed tape
Output of B & K 2112 amp
w/ "A" weighting
100
200
500
1000
2000
5000
10000
20000
c/s

FIGURE 2

H. No manufacturer's specifications or operating instructions were included with the test request; therefore, no reference is made to minimum specifications, etc. The data collected and presented should be regarded as performance characteristics.

I. The addition of pre-emphasis to the higher frequencies resulted in an improvement over the engineering model of 25 dB at 5000 Hz with the unit mounted on a 4' x 4' x 3/4" plywood panel.

J. In most instances Band Pass Filtering (200-5000 Hz) reduced the noise present in the output signal.

K. The SWM-25 is recommended for operational use on the basis of the principle of operation, performance during operational tests, and its ability to withstand environmental stresses. This device should find widespread use as a tool for audio operations. Low temperature applications will be limited if a local battery supply is used.

III. RECOMMENDATIONS

A. The low frequency response (below 500 Hz) should be reduced or provision made for a companion filter to be used with the LP equipment.

B. The method of sealing the oil reservoir should be revised to withstand temperatures up to 160°F.

C. The cabling should be placed within a single jacket and a 4 wire input considered. This would enable the battery or DC supply to be independent of the signal return.

D. Complete specifications, schematic diagrams, operational instructions, and application notes should be provided with each unit.

E. One Engineering Model of the transducer should be resubmitted to ESG for intelligibility testing to compare results with those of the prototype. This would determine whether pre-emphasis of the high frequencies improves intelligibility.

F. A companion filter should be considered for use as an accessory to the transducer. Perhaps a redesigned version of an existing filter such as that used in the SWM-3 Contact Microphone Kit would be suitable.

G. Three units from the first production efforts should be submitted to ESG for evaluation of critical parameters and for comparison with the prototype.

IV. TESTS AND RESULTS

A. Test Flow Chart

	#0	#1	#2
1. Electrical Tests			
Noise Level	X		
Frequency Response (0.01g)			X
Frequency Response (Free Field)	X	X	X
1/3 Octave Noise Analysis	X	X	X
Frequency Response w/200-5000 Hz BPF	X	X	X
Frequency Response in a 10" x 10" x 18" Block	X	X	X
Frequency Response on a 4' x 4' x 3/4" Panel	X	X	X
2. Environmental Tests			
High Temperature Storage		X	
Low Temperature Storage		X	
Temperature-Humidity (10 day) MIL-T-5422E			X
Vibration (MIL-STD-810B)	X		
Drop	X		
3. Psycho-Acoustic Test (Intelligibility)	X	X	X
4. Articulation Index Test	X	X	X
5. Operational Tests			
Brick Wall	X		
Concrete Wall	X		
Cinder-Block Wall	X	X	

B. Electrical Tests

1. Noise Level

a. Test The noise level of the transducer was measured both with the power to the amplifier ON and OFF. To reduce the ambient noise pick-up to a minimum, the transducer was wrapped in a layer of duct seal approximately 1 inch thick and the measurements made with the transducer located on a rubber band suspension in an anechoic chamber.

b. Result The equipment noise with the transducer amplifier power off was -108 dB (re 1 volt; open circuit voltage). With the amplifier power "ON" the noise measured with a 2112 B and K Audio Spectrometer Amplifier was as follows:

Weighting	Noise Output
A	-87 dB
B	-86 dB
C	-86 dB
Linear	-83 dB

2. Frequency Response (0.01g)

a. Test The frequency response and sensitivity of the transducer were measured at a constant acceleration along the longitudinal axis of the transducer. The transducer was attached to the vibration platform of a Derritron Model AV-50 Vibration Unit. A control accelerometer (Endevo #KC52, model 2226) was attached to the platform and the output was set for a constant acceleration of 0.01g at 1000 Hz via a compression circuit in the B and K 1022 Beat Frequency Oscillator. The oscillator output was used to drive the Derritron AV-50 Vibration Unit.

b. Result The upper curve of Figure 2 shows the response of the transducer with no filtering of the output voltage employed. The lower curve shows the same response curve with an "A" weighting curve filter on the output. Note the reduction in response below 500 Hz.

3. Frequency Response (0.1g)

a. Test Response and sensitivity measurements were made along two mutually perpendicular axis, each perpendicular to the longitudinal axis of the transducer.

b. Result The sensitivity of the transducer to vibration perpendicular to the longitudinal axis was significantly less than when the acceleration was applied along the longitudinal axis of the unit. In order to obtain the same peak output, it was necessary to increase the acceleration from 0.01g to 0.1g (or 20 dB). The response characteristic showed numerous resonances and dropouts across the audio spectrum in this position and the results varied substantially when the SWM-25 was rotated 90° about its axis.

4. Frequency Response (Free Field)

a. Test The transducer was suspended in the anechoic chamber and the output measured as if the transducer were a microphone in a field of a constant 74 dB SPL. Two measurements were made; one with the transducer uncovered and the other with a one inch covering of duct seal.

b. Result The curves of Figure 3 illustrate two significant features, the pre-emphasis peak at 5500 Hz and the attenuating characteristics of the duct seal. Note that the frequencies below 2000 Hz are enhanced while the frequencies above 2500 Hz are attenuated sharply with the signal down approximately 20 dB at 5000 Hz.

5. 1/3 Octave Noise Analysis

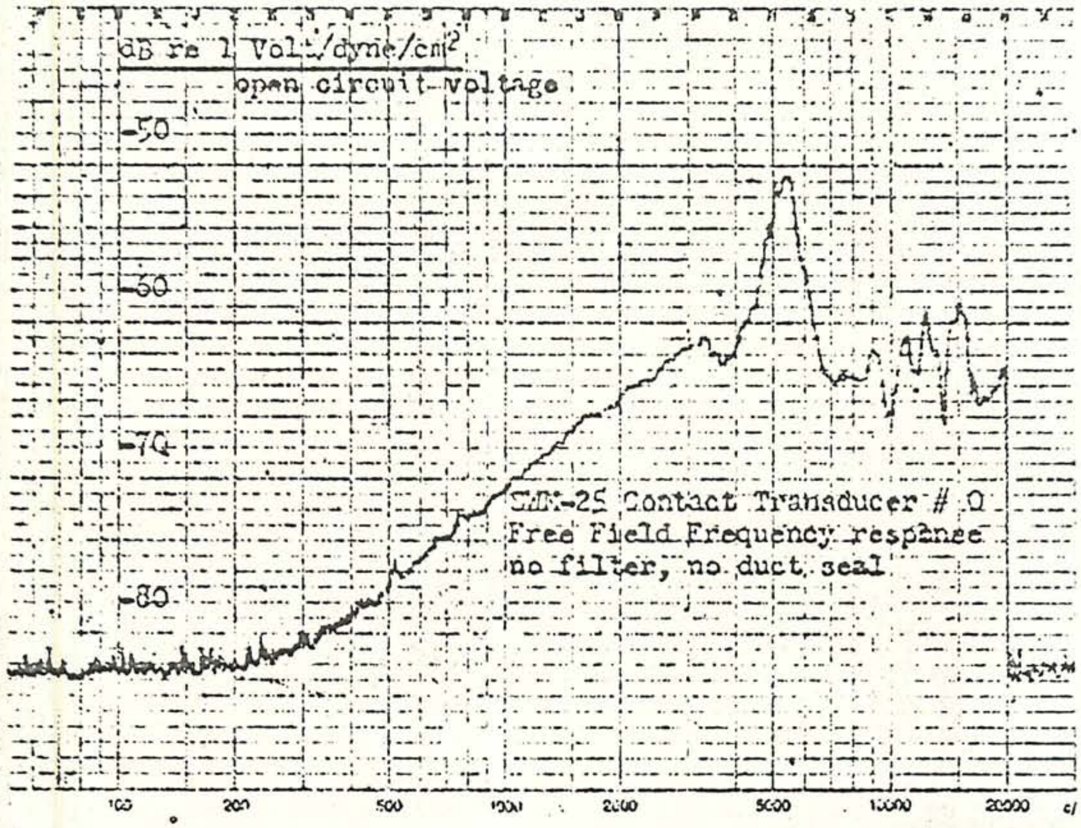
a. Test Two transducers were covered with duct seal and placed in the anechoic chamber on a rubber band suspension. The noise output was then measured in 1/3 octave bands and with "A", "B", "C", and Linear filtering.

b. Result Figure 4 shows the spectral composition of the broad band noise. Note that from both curves a 4 to 5 dB difference exists between the linear measurement and the "A" weighted measurement. However, in the instance of Unit #1, the difference is due primarily to low frequency noise (below 1000 Hz) while Unit #0 exhibits more noise in the higher frequencies (above 1000 Hz).

6. Frequency Response with a 200-5000 Hz Band Pass Filter

a. Test During the course of the test program changes in the noise level of Unit #2 were audibly apparent. This change was measured by placing the transducer in a free-field (and enclosed in duct seal) and plotting the frequency response characteristic.

b. Result The noise level change is obvious in the bottom curve of Figure 5 as compared with the characteristic response of another transducer. Changes of 6-7 dB in the noise level were observed as shown. The time represented by the frequency scale is 44 seconds.



74 dB SPL

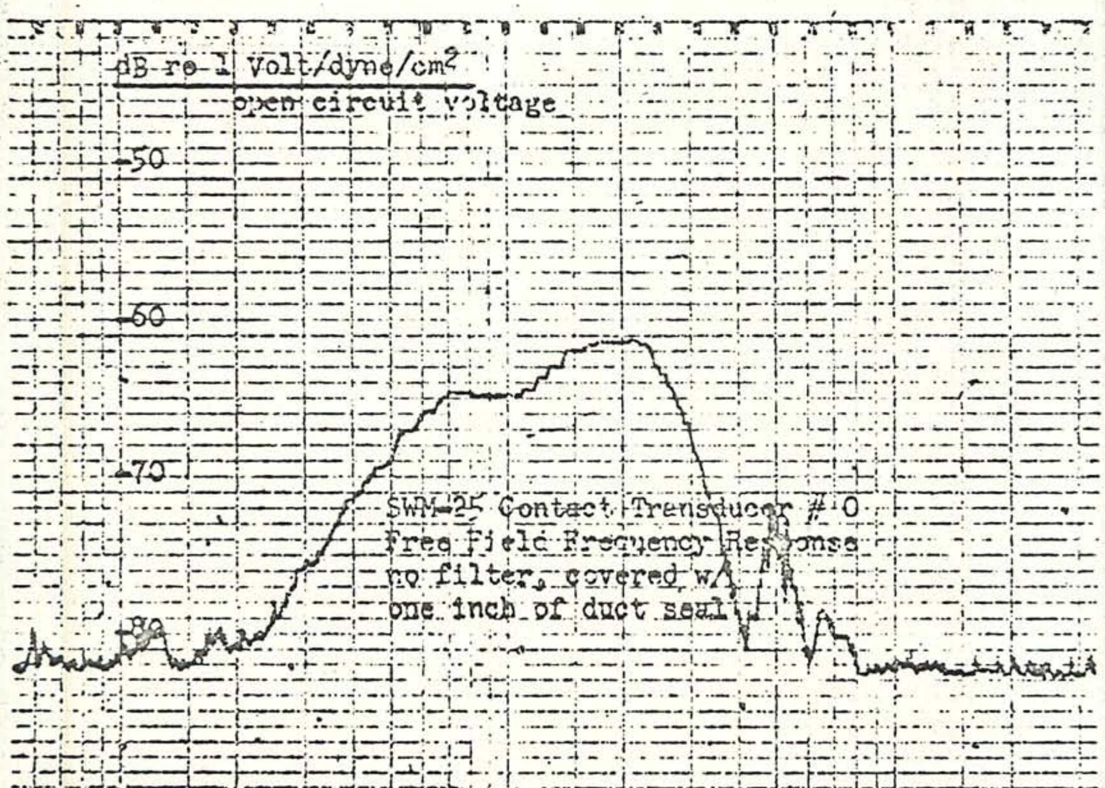
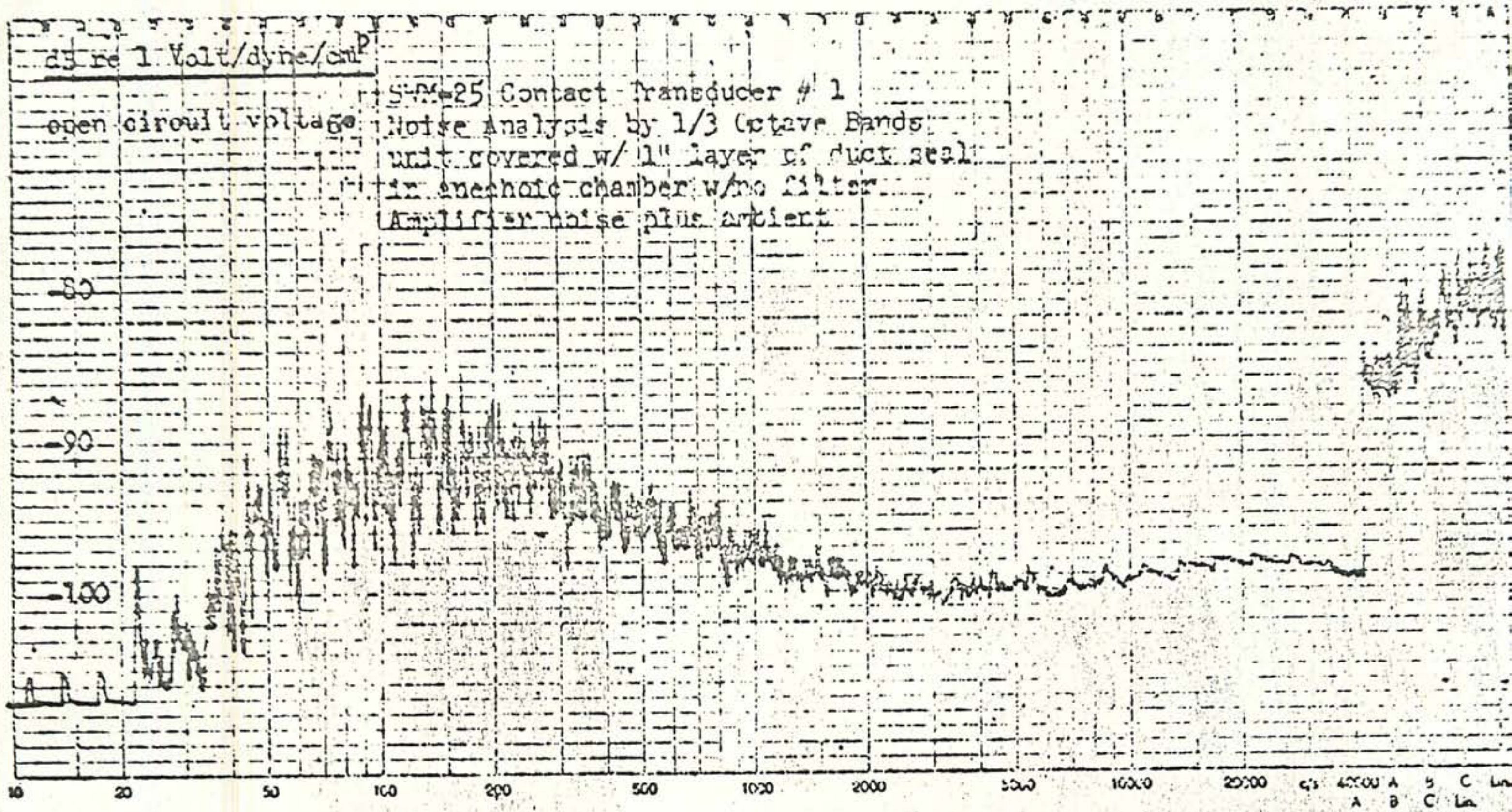


FIGURE 3


dB re 1 Volt/dyne/cm²
open circuit voltage
SVM-25 Contact Transducer # 1
Noise Analysis by 1/3 Octave Bands
unit covered w/ 1" layer of duct seal
in anechoic chamber w/no filter
Amplifier noise plus ambient
-80
-90
-100
10
20
50
100
200
500
1000
2000
5000
10000
20000
c/s
40000

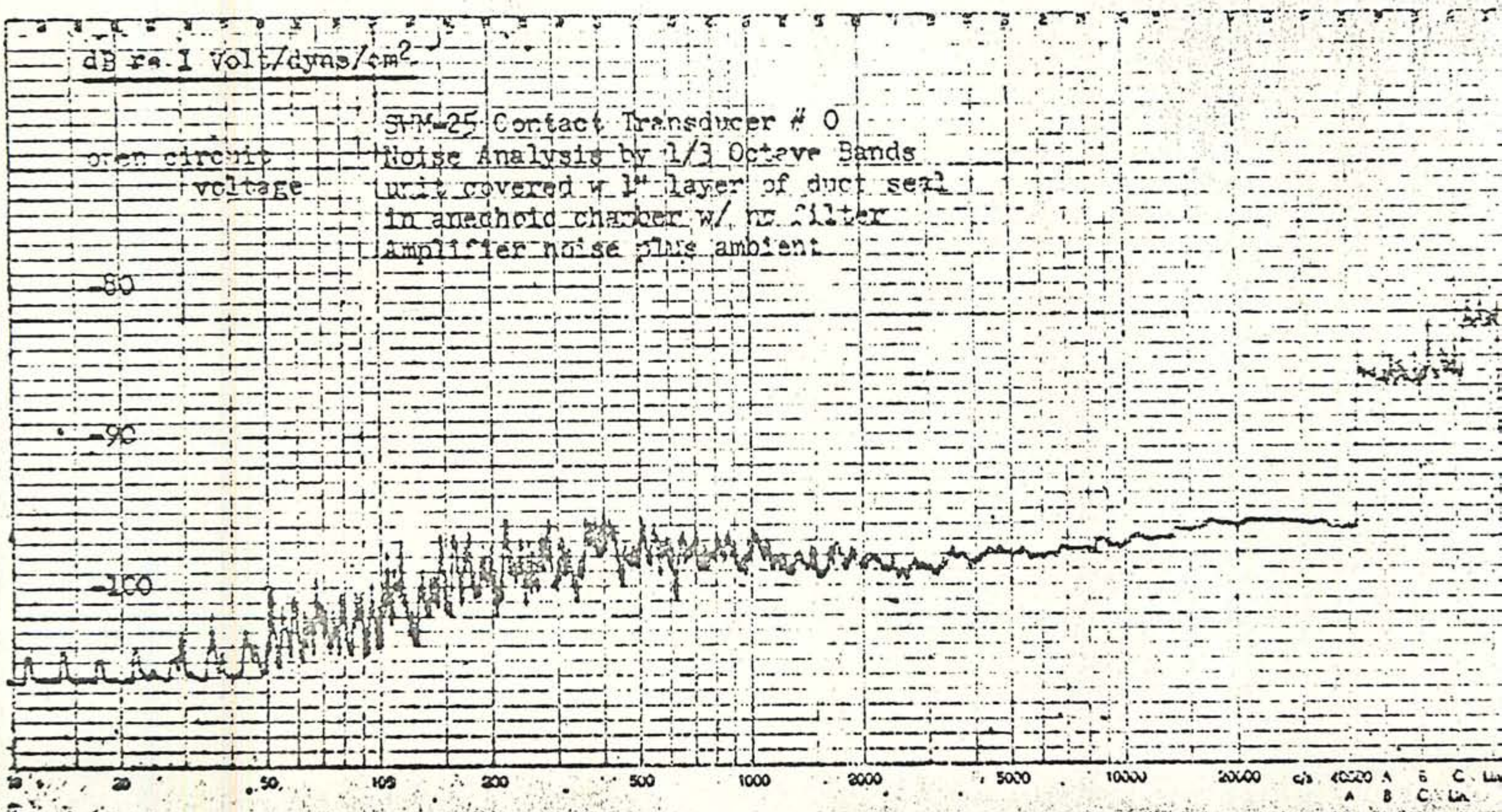
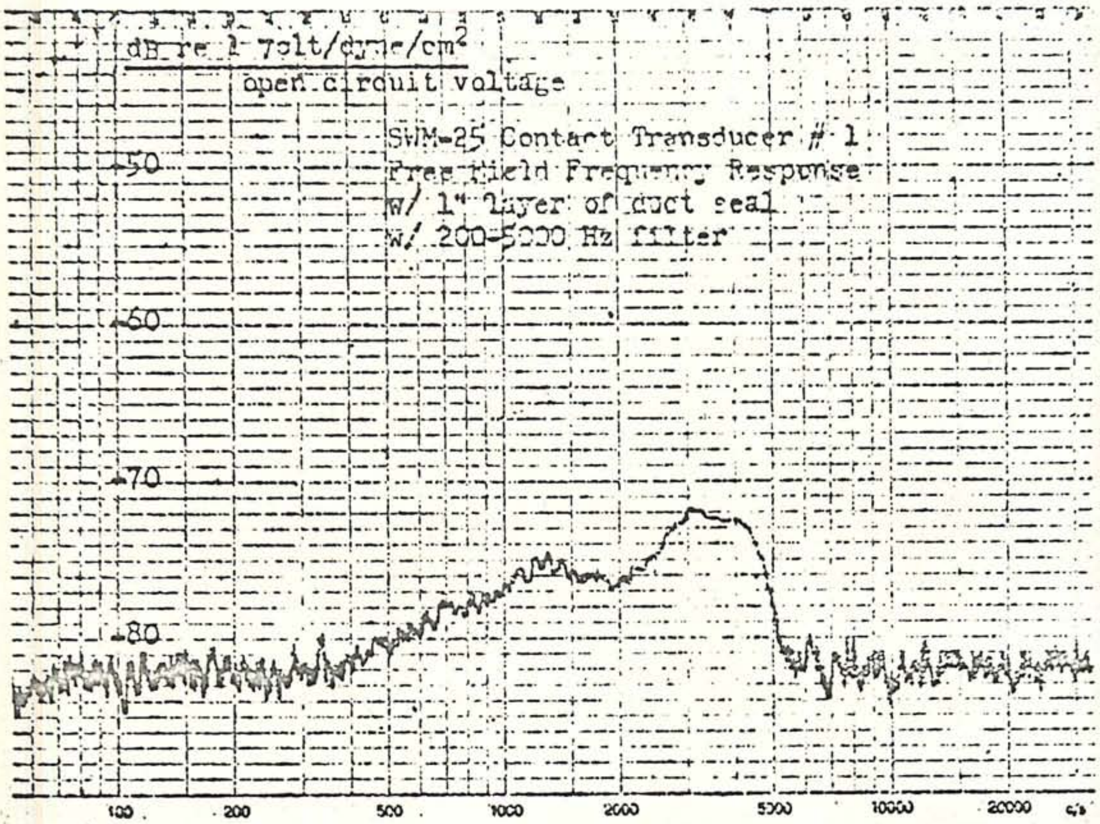

dB re 1 Volt/dyne/cm²
open circuit voltage
SVM-25 Contact Transducer # 0
Noise Analysis by 1/3 Octave Bands
unit covered w/ 1" layer of duct seal
in anechoic chamber w/ no filter
Amplifier noise plus ambient
-80
-90
-100
10
20
50
100
200
500
1000
2000
5000
10000
20000
c/s
40000

FIGURE 4


dB re 1 Volt/dyne/cm²
open circuit voltage
SWM-25 Contact Transducer # 1
Free Field Frequency Response
w/ 1" layer of duct seal
w/ 200-5000 Hz filter
-50
-60
-70
-80
100
200
500
1000
2000
5000
10000
20000

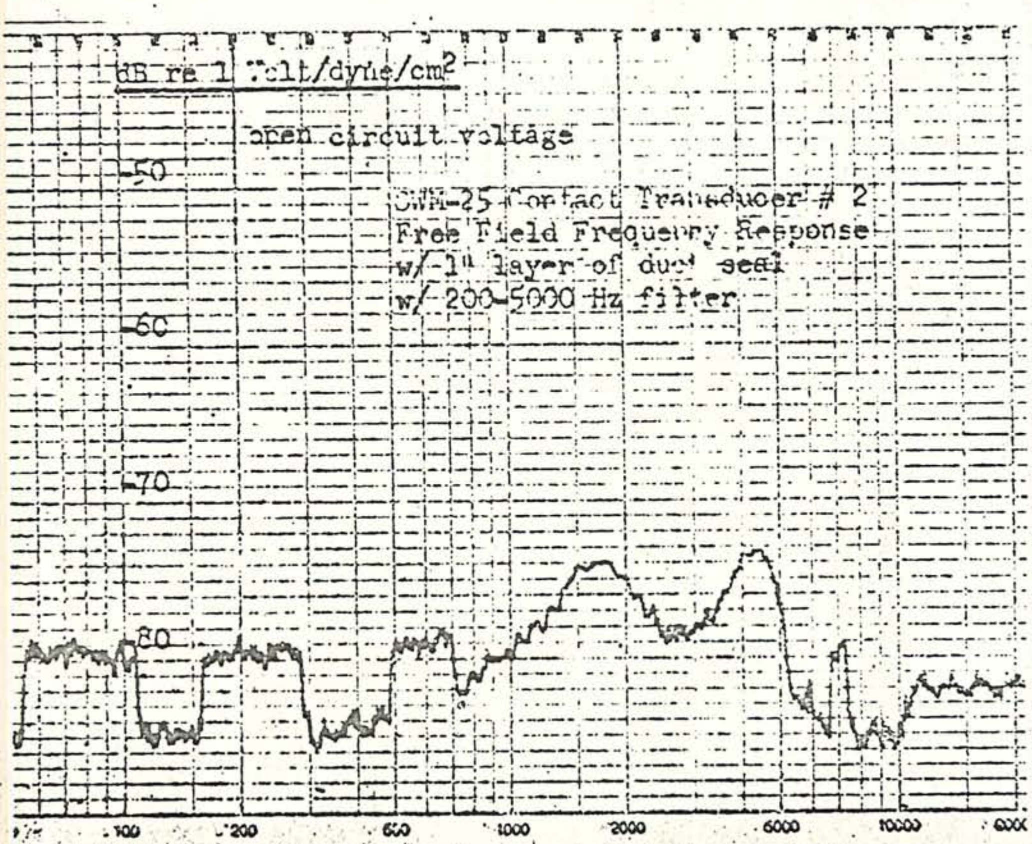

dB re 1 Volt/dyne/cm²
open circuit voltage
SWM-25 Contact Transducer # 2
Free Field Frequency Response
w/ 1" layer of duct seal
w/ 200-5000 Hz filter
-50
-60
-70
-80
100
200
600
1000
2000
6000
10000

FIGURE 5

7. Frequency Response in a Concrete Block (10" x 10" x 18")

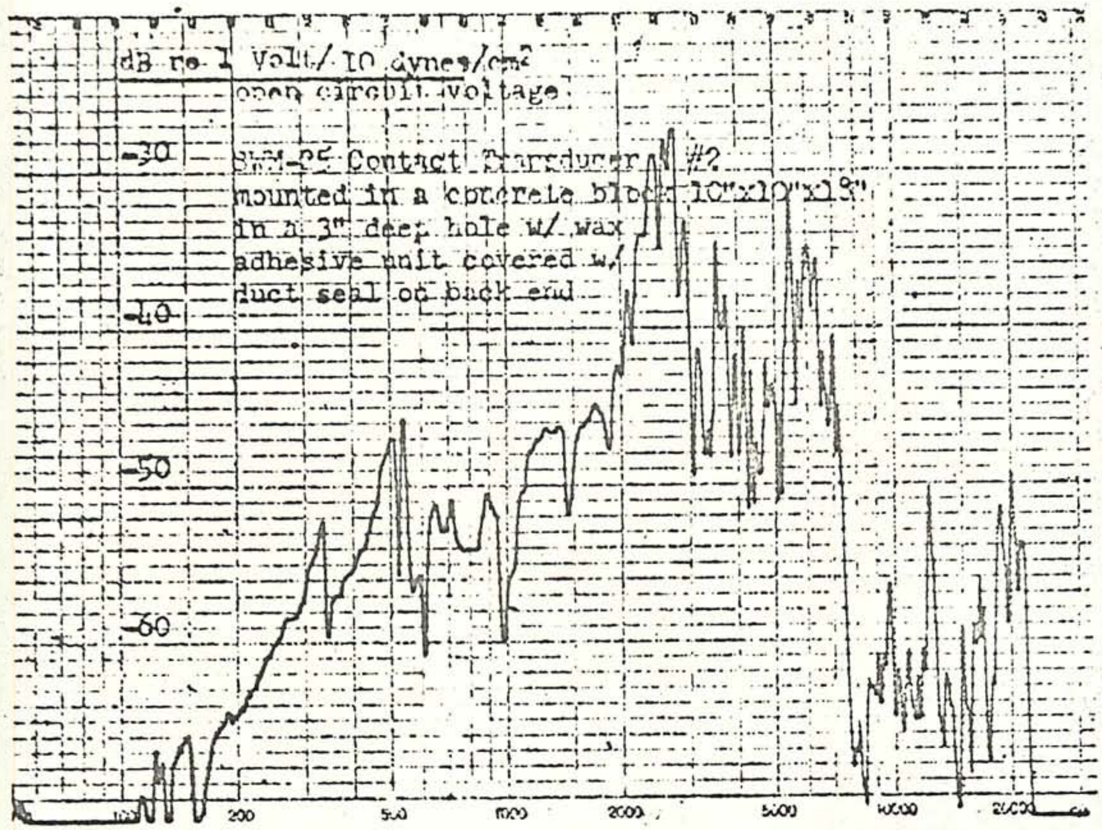
a. Test The transducer was placed in a 1 1/8" diameter hole, drilled in the concrete block so that flat surface facing the sound source was 10" x 18". The depth of the hole was 2", 3", and 4" for successive tests. The transducer was set in melted wax at the bottom of the hole and the wax was allowed to harden. This ensured a rigid coupling to the block and still allowed the transducer to be removed easily for additional tests.

b. Result Even though a 10" x 18" surface is not representative of a wall constrained on four perimeters, the response of the transducer was, nevertheless, quite acceptable. Figure 6 shows the response of two different transducers set in the 3" deep hole with wax coupling. Note that the output of the transducer set in the block and sealed with duct seal is approximately the same at 600 Hz as it is at 6000 Hz with only two or three significant anti-resonances of more than 10 dB; furthermore, these anti-resonance points are very narrow in bandwidth.

8. Frequency Response on a 4' x 4' x 3/4" Plywood Panel

a. Test The transducer under test was fastened to a 4' x 4' x 3/4" plywood panel and a constant SPL of 74 dB was maintained at the face of the panel throughout the frequency range of 50-20000 Hz.

b. Result The upper curve of Figure 7 shows the response of the prototype SWM-25 Transducer. The bottom curve shows the response of the engineering model version of the SWM-25 called the Pinholeless Microphone (ESG Project 68-110).


dB re 1 Volt/ 10 dynes/cm2
open circuit voltage
SWM-25 Contact Transducer #2
mounted in a concrete block 10"x10"x18"
in a 3" deep hole w/ wax
adhesive unit covered w/
duct seal on back end
-30
-40
-50
-60
100
200
500
1000
2000
5000
10000
20000

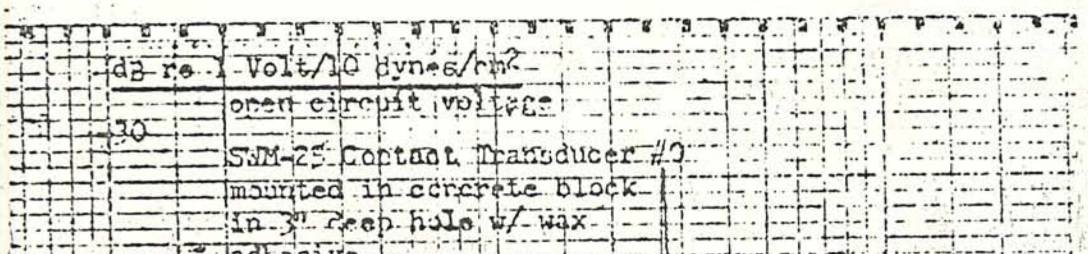
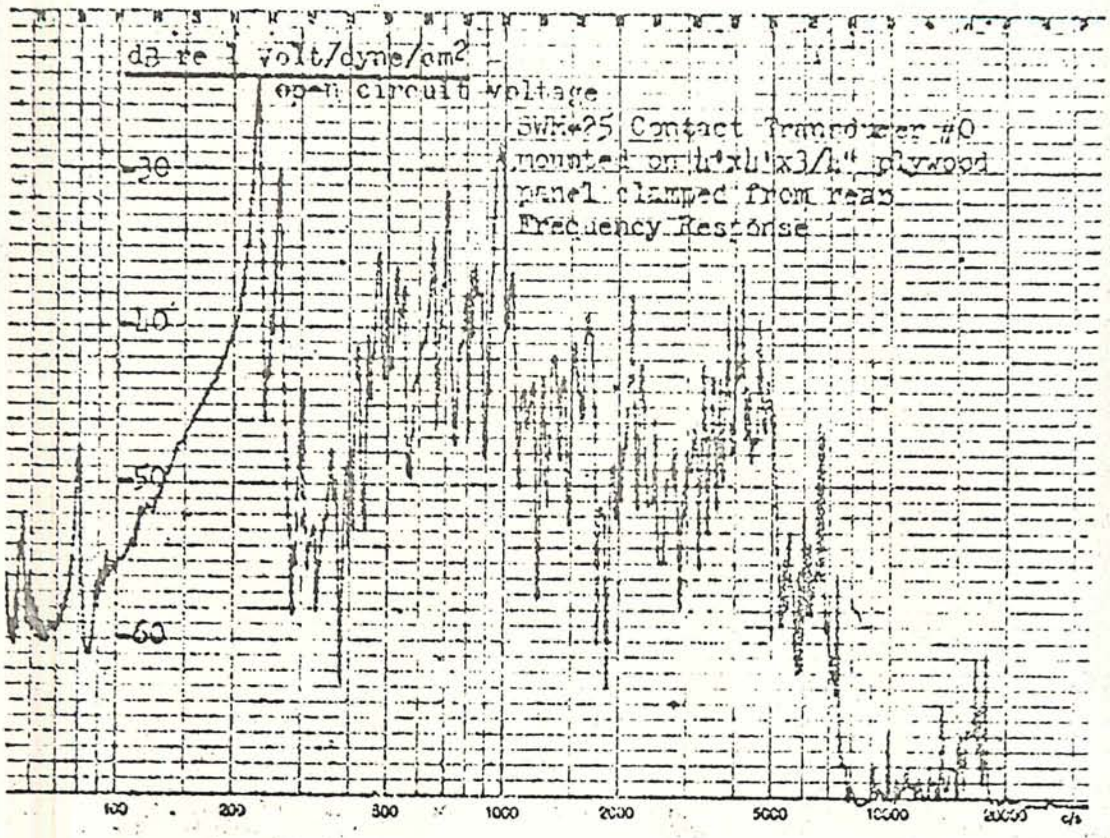
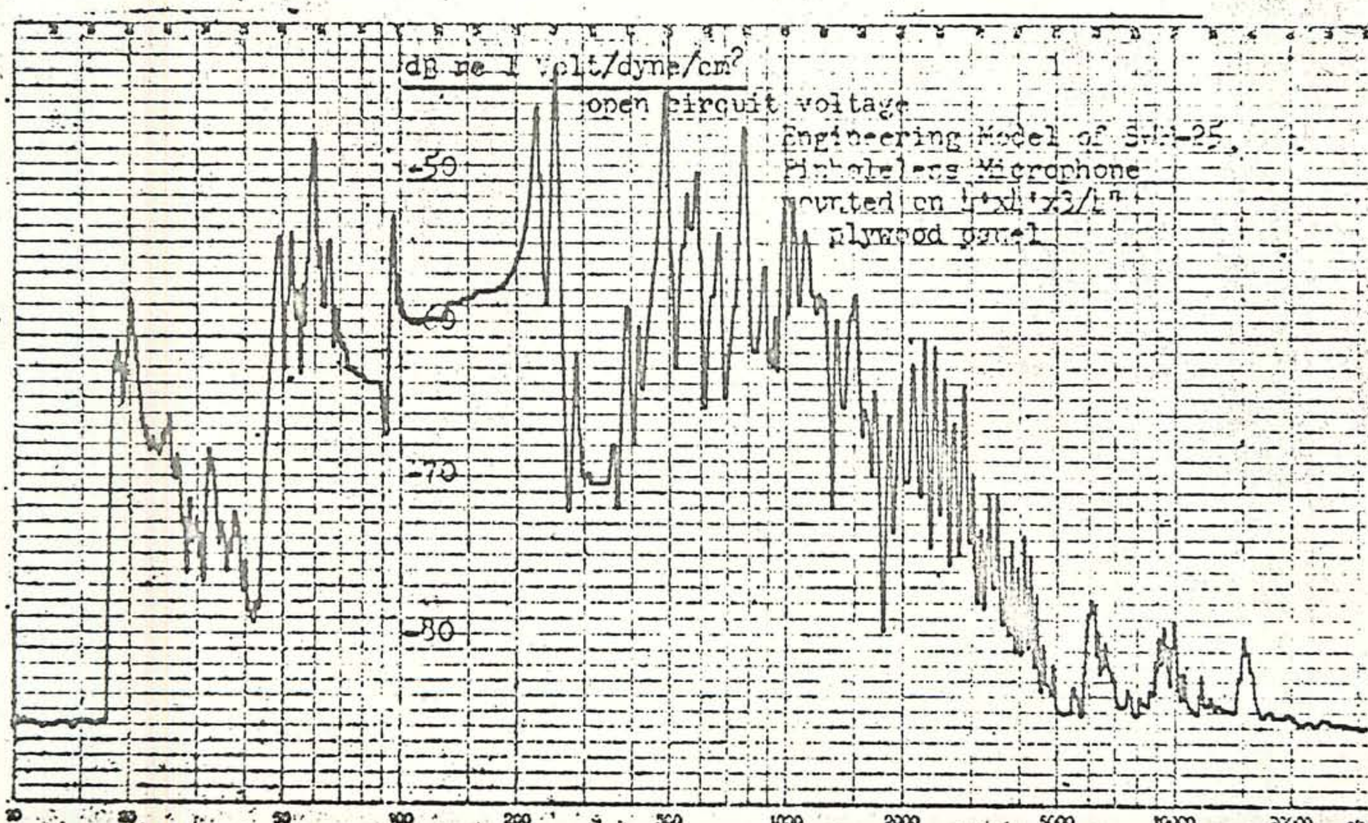

dB re 1 Volt/10 dynes/cm2
open circuit voltage
-30
SWM-25 Contact Transducer #3
mounted in concrete block
in 3" deep hole w/ wax
adhesive
-40
-50
-60
100
200
500
1000
2000
5000
10000
c/s

FIGURE 6



dB re 1 volt/dyne/cm²
open circuit voltage
SWK-25 Contact Transducer #0
mounted on 4'x4'x3/4" plywood
panel clamped from rear
Frequency Response
-30
-40
-50
-60
100
200
500
1000
2000
5000
10000
20000
c/s



dB re 1 volt/dyne/cm²
open circuit voltage
Engineering Model of SWK-25
plywood panel
-50
-60
-70
-80
20
50
100
200
500
1000
2000
5000
10000
20000
c/s

FIGURE 7

Because the Pinholeless Microphones submitted for test were withdrawn from the test program, this is the only comparison curve available. Note that the Prototype SWM-25 Transducer maintains 25 dB S/N ratio from 150-5000 Hz while the Engineering Model SWM-25 has excessive low frequency response (below 200 Hz) and starts losing S/N above 2000 Hz approaching the noise level at 5000 Hz.

C. Environmental Tests

1. High Temperature Storage

a. Test One transducer was submitted to the High Temperature Storage Test (160°F for 3 days).

b. Result No degradation was observed; however, the sealant did allow some oil to escape and cover the outside of the transducer with a dark film.

2. Low Temperature Storage

a. Test One unit was subjected to the Low Temperature Storage Test for target equipment (-40°F for 3 days).

b. Result No degradation was observed.

3. Temperature-Humidity Exposure

a. Test One unit was subject to the standard 10-day Temperature-Humidity Test for Microphones (MIL-T-5422E).

b. Result No degradation was observed.

4. Vibration

a. Test One unit was submitted to the Standard Vibration Test for target equipment (per MIL-STD-810B).

b. Result No degradation was observed.

5. Drop

a. Test One unit was dropped a total of 3 times on the flat face of the end of the cylinder and 3 times on the side of the cylinder from a height of 36 inches onto a steel plate.

b. Result No degradation was observed.

D. Psycho-Acoustic and Articulation Index Tests

1. Psycho-Acoustic Test

a. Test To evaluate the transducers from a subjective point of view, High Fidelity Word List Tapes were played back through a speaker and the transducers were installed in a concrete block (10" x 10" x 18"). The block was positioned at a distance of 14 ft. from the speaker. The SPL measured at 4 feet from the speaker was 71 dB. The output of the SWM-25 was recorded on a Uher 4000L Tape Recorder. The tapes were then sent to a contractor for processing by a Listening Panel.

b. Result The results of these tests will be reported by an addendum memorandum at a later date.

2. Articulation Index Testing

a. Test The articulation index of the transducers set in the block (as for the Psycho-Acoustic Testing) was measured for comparison with the results to be obtained from the Psycho-Acoustic test report.

This test (developed by RCA) as yet has not been proven valid for contact transducers and the results should not be used to draw any conclusions.

b. Result The articulation indices measured for the transducers were as follows:

Condition 22 (#2)	51%
Condition 23 (#1)	35%
Condition 24 (#0)	48%

The articulation index for a "D" Microphone with no intervening hinderances placed in the same position (14 ft. from the speaker) was measured to be 76.0%.

E. Operational Tests

1. Brick Wall (8" thick)

a. Test In this test the transducer was inserted into a brick wall (double brick, 3 3/4" each wall with 1/2" air space for a total wall thickness of 8") at successive 1" depths to within 1" of the opposite target wall surface.

b. Result The audio was comparable with that from a microphone/pinhole installation. The depth into the wall seemed to make no difference on the quality of the audio nor was there a noticeable increase in intelligibility as the hole was drilled nearer to the target wall. The audio at a depth of 2" was approximately the same as when the hole was 7" deep.

2. Concrete Wall (8" thick)

a. Test A test similar to the one made with the brick wall was conducted. In this instance the entire target wall was covered with a rather loose fitting wooden paneling.

b. Result The audio was significantly lower in level than with the brick wall. This is attributed to the wooden paneling covering the target side of the wall. In this instance a microphone/pinhole combination would probably prove superior. The audio was intelligible; however, the Signal/Noise ratio was considerably less than observed with the brick wall installation.

3. Cinderblock Wall

a. Test Although cinderblock walls are not commonly found in usual operations, the unit was placed on a cinderblock wall to observe the results with this construction material. The transducer was attached to the LP side of a common wall with epoxy glue and no hole was drilled.

b. Result The audio recovered was of good quality except when an air-handling system located directly above the wall was operating. Since the principle of operation of the transducer is to convert conducted sound through solid materials into electrical signals, wall noise will always be a concern when using the transducer. The greater sensitivity of the transducer to vibration signals on axis as compared to vibration perpendicular to its axis may diminish off-axis signals somewhat.

V. OPERATIONAL SUITABILITY EVALUATION

A. Physical Examination

1. Size - The 1" diameter of the transducer allows it to be placed in either a 1" or 1 1/8" diameter hole (this is an important and desirable characteristic).

2. Connector - The small wires used to provide DC power to the unit and to recover the signal generated by the unit should be changed. A single jacket multi-wire conductor is recommended. The method used for sealing the area where the wires enter may have to be revised. The compressible washer seems rather inadequate in view of the possibilities available for making the transducer impervious to almost any environmental stress.

B. Instructions

1. Operating Instructions - No operating instructions were supplied. A pamphlet outlining basic operational instructions should be prepared.

2. Diagrams and Schematics - The schematic diagram of the transistor amplifier was adequate; however, the color code noted on the 3 wires was incorrect. This should be corrected for future models. The overall response curve of the transducer/amplifier combination was not included although a curve of the bipolar amplifier relative to the FET amplifier used in the Engineering Model was available. Updated drawings and sketches of the prototype model were not available.

3. Recommendation - It is strongly recommended that all aspects of the needed information be presented for future production evaluation. Also the leads should be labeled or color coded and encased in a single jacket.

C. Installation

No particular problems are envisioned in handling the unit for installation unless it is to be installed in a hole deeper than 3". If the hole is deeper than 3", a method of grasping the unit from behind (i.e., a rod that screws into the base) should be provided should relocation of the unit be necessary. An adhesive that will form a rigid bond between the transducer and the surrounding environment is recommended. In considering the SWM-25 Transducer for an installation it should be kept in mind that the wall in which it is concealed will be excited by sounds on both sides of the wall. The transducer will reproduce sounds occurring on either side of a wall and the ambient sounds on the LP side of common wall situations will be mixed with the target audio.

D. Compatibility

Compatibility for use with existing equipment using microphone inputs should be examined in the view of the 1.35 VDC requirement for the transducer. The powering problems should be outlined in the instructions. Recommendations as to the type and brand of battery to be used should be covered thoroughly. Low temperature applications will probably be limited if local battery supply is required. Remote and local powering of the devices should be thoroughly examined for long term applications.

E. Security Considerations

The envisioned use of the device will enhance the security of operations; especially with regard to the hazards of drilling pinholes through common walls. The most important characteristic displayed by the transducer is the possibility of attacking common wall situations without drilling through to the target side and possibly without drilling at all.

F. Summary

The SWM-25 Contact Transducer is recommended for operational use. Its potential for eliminating the hazards involved with drilling common walls is obvious. Undoubtedly, numerous occasions will arise where the transducer will experience problems arising from the wall environment and the acoustic problems associated with the target. However, the device should find use in many applications where microphone installation is impractical or involves high risk.